490

A REMOTE CONTROLLED UNDERWATER PHOTOGRAPHIC SURVEILLANCE SYSTEM

by Paul J. Kruse, Jr.

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FISH AND WILDLIFE SERVICE

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ABSTRACT

An underwater motion picture camera system has been developed and used to study midwater trawling operations. The photographic equipment is handled by remote control from the vessel deck and records both trawl mechanics and fish escape reactions. The equipment has been tested and placed in operation in studies in the Gulf of Mexico.

INTRODUCTION

During the past 5 years, the Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Pascagoula, Miss., has been investigating the pelagic school fishes of the northern Gulf of Mexico. The U.S. Fish and Wildlife Service exploratory fishing vessel Oregon has been assigned to the investigation. In the first year, effort was devoted largely to sampling and qualitatively surveying the resource (Thompson, 1959). In subsequent years, attention was turned to assessing the abundance and availability to trawling gear of the fish species involved.

As the work progressed, several difficulties became evident (Bullis, 1961). Calculations of abundance and availability are dependent on a knowledge of the effectiveness of the sampling device being used. The effectiveness of sampling in this study was difficult to assess, however, as the sampling device was out of sight, at the end of hundreds of feet of cable, and beneath several hundred feet of water.

Visual observation appeared to offer the best overall synchronous study of the many different, but related, events taking place during midwater trawling operations. Films made by diver photographers would have been preferred, however, the physical conditions encountered during field trawling operations made this approach impractical. A special remote controlled motion picture camera system was subsequently developed, at the Pascagoula Base, to overcome the limitations of divers and permit visual recordings of midwater trawling operations.

REMOTE CONTROLLED PHOTOGRAPHIC SYSTEM AND ACCESSORIES

The remote controlled photographic system permitted cameras to be mounted on the midwater trawl itself, and yet be controlled by an operator on board the Oregon. The system can also be synchronized with data received from a trawl headrope transducer. The cameras are compact and rugged enough to operate under any conditions that permit trawling.

The photographic system (fig. 1) consists of three electrically driven motion picture cameras in underwater housings that are fastened to the trawl (fig. 2). The cameras are connected to the towing vessel by an electrical cable that is plugged into a master control box (fig. 3), connected to a shipboard 110-volt a.c. outlet. Camera operation is controlled by a switch on the control box. Converters in each underwater housing change the 110-volt a.c. current to the 24-volt d.c. required for the camera motors.

Basic Camera Modifications

The N-9 GSAP U.S. Air Force gun camera (also known as TKB-3A) is the basic unit for this system. It was chosen because of its compact size, ruggedness, availability, adjustable shutter opening, rapid film loading, and choice of 50- or 100-foot film magazines. The three film speeds available on the standard cameras are 16, 32, and 64 frames per second (f.p.s.). Other frame rates are available as special conversions. The basic cameras are modified as follows:

1. The 0- to 3-second overrun mechanism is removed.
2. The small disk tension spring in the film magazine clamp, located at the rear of the camera body, is removed to assure a more positive connection between the film magazine and the camera body.
3. The remote shutter adjusting mechanism is not used. This reduces the number of conductors necessary in the underwater cable.

Film Magazines and Modifications

Two sizes of underwater cameras were used for the midwater trawl studies and offered greater flexibility than if only one were used. A 400-foot film capacity camera permits 8 minutes running time, at 32 f.p.s. It is used

Note.--Paul J. Kruse, Jr., Fishery Biologist, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Pascagoula, Miss.

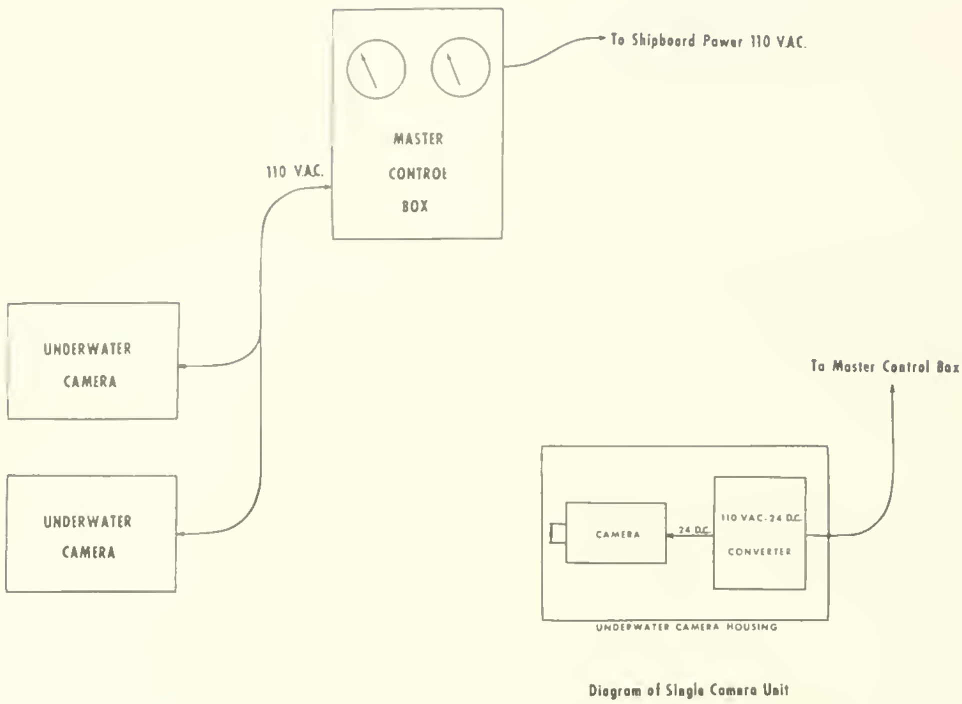


Figure 1.--General schematic diagram for underwater camera system.

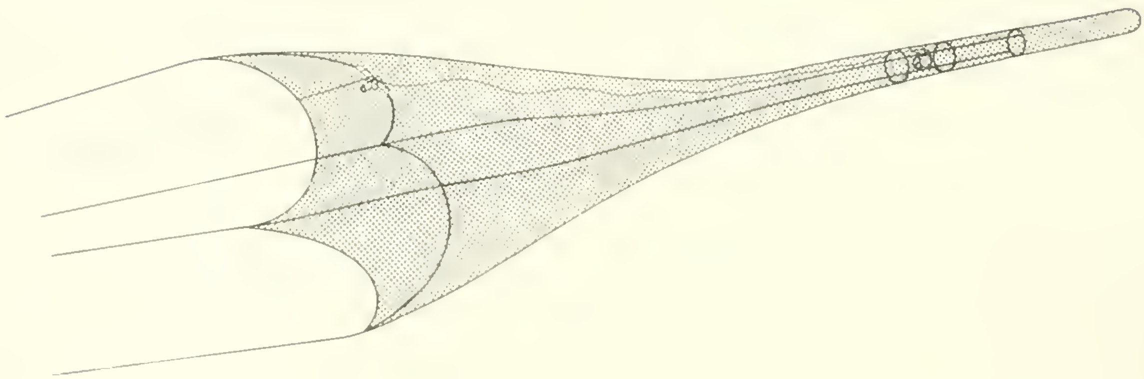


Figure 2.--Midwater trawl schematic diagram showing location of cameras on headrope and in throat.

wherever its water resistance will not be a problem. Smaller 50- and 100-foot capacity cameras, although they permit only 1 or 2 minutes running time at 32 f.p.s., are used where size is a limiting factor.

Two standard types of interchangeable GSAP film magazines are used in this system; a 50-foot LB-4A and a 100-foot 6230-B. The 400-foot film capacity is obtained by modifying an LB-4A magazine for attachment of a Bell & Howell 132 BM 400-foot external film magazine (figs. 4 and 5).

The LB-4A and 6230-B magazines are equipped with single-toothed sprockets as standard equipment. These do not maintain sufficient grip on the sprocket holes. Their replacement with double-toothed sprockets (available as accessories) is necessary.

The LB-4A and 132 BM magazines (for 400-foot capacity) are coupled by attaching a 132-BM mounting plate to the top of an LB-4A magazine (fig. 6), after matching holes are machined at the rear or the top of the LB-4A magazine. The film supply and takeup shafts in the LB-4A are removed next since their functions are accomplished by the 132-BM magazine and the shafts would interfere with the new film path.

The existing film supply roller is moved under the front opening (film inlet) to prevent film scraping. An auxiliary takeup film roller is installed under the rear opening (film exit) for the same purpose. Holes remaining in the LB-4A magazine, after modification, are plugged to prevent light leaks. A conversion kit is available commercially.

Figure 3.--Camera master control box.

Film Takeup Drive

The LB-4A and 6230-B magazine provide their own film takeup drive. However, an external drive motor is necessary when the 132-BM magazine is used (figs. 4 and 7). Any 24-volt d.c. or 110-volt a.c. electrical motor with a clockwise rotation may be used. The pulley on the takeup motor shaft is coupled to the magazine takeup pulley by means of a spring belt from a motion picture projector. A 120-r.p.m. takeup motor is necessary for proper film tension. The film takeup core and film act as a pulley of increasing diameter. When the camera is first started, the diameter of the almost bare takeup core is roughly 2 inches. The core-film diameter at the end of a 400-foot run is approximately $6\frac{1}{2}$ inches. The speed at which the camera feeds exposed film into the magazine takeup chamber remains constant at any given frame rate. The rotation speed of the takeup core will gradually decrease as film is accumulated. The 120-r.p.m. motor will rotate the takeup core fast enough at the beginning of a film roll to keep proper tension on the exposed film. As the core-film diameter increases, slippage of the spring belt compensates for the decrease in r.p.m.'s.

Camera Power Supply

Two voltages are necessary for the operation of this system. Because of its availability

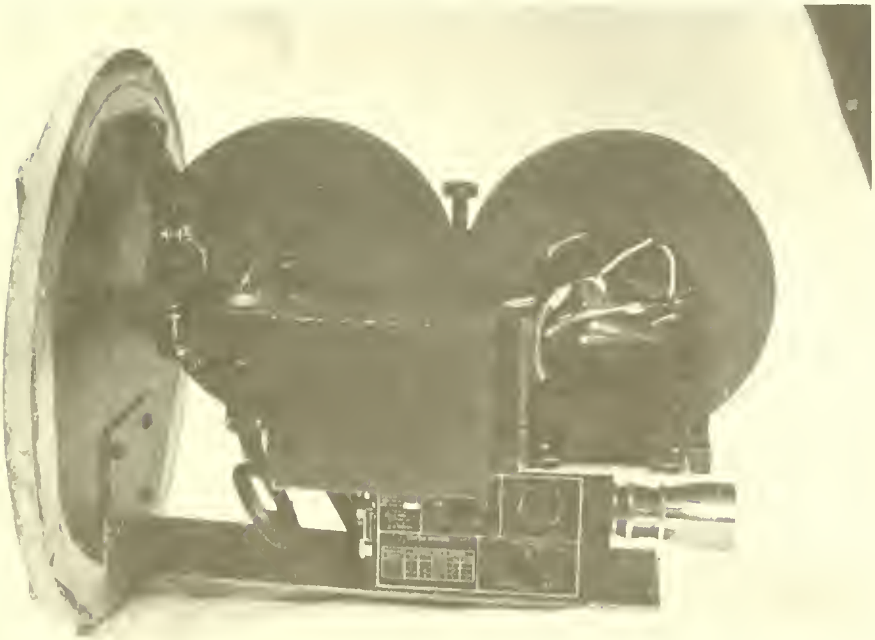


Figure 4.--Large camera unit attached to rear underwater housing port. The metal covered takeup motor and tape-wrapped power supply are located above the camera and in front of the 400-foot film magazine.

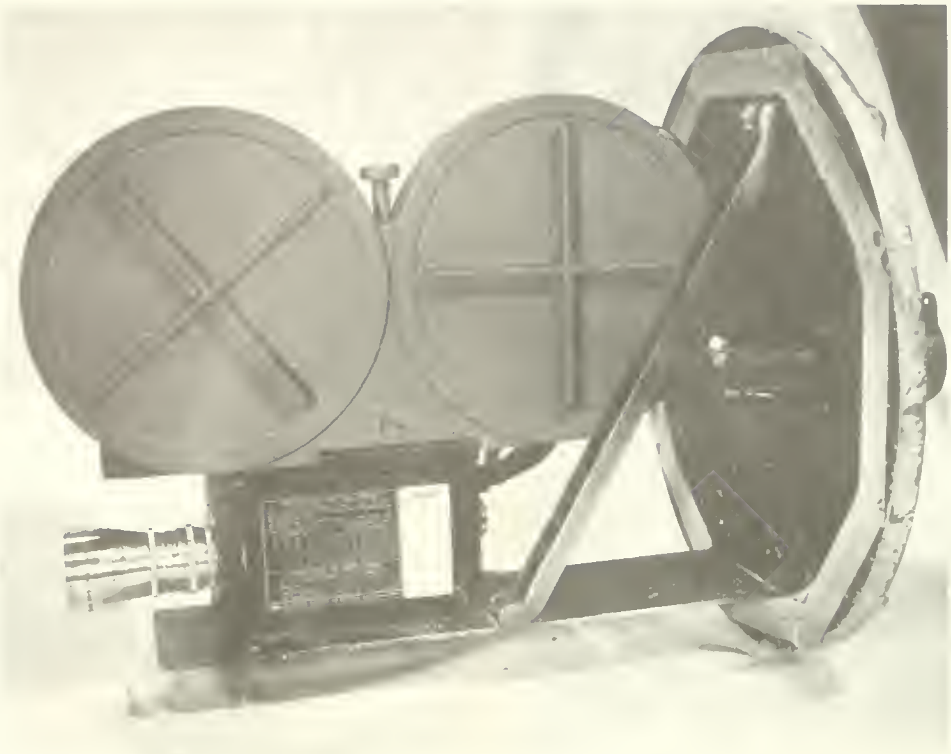
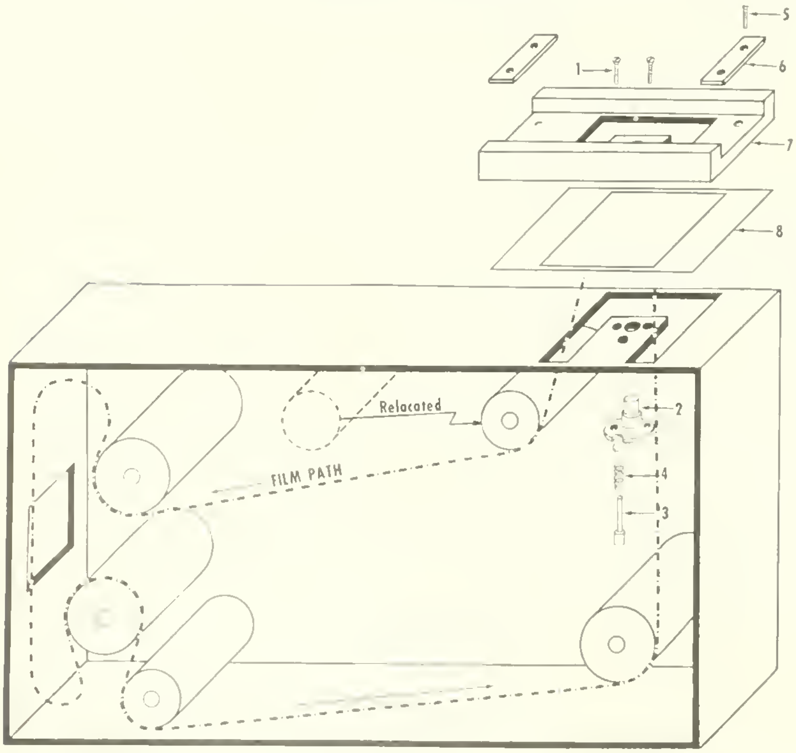


Figure 5.--400-foot film magazine and mounting plate on top of LB-4A magazine. Wire leads from Joy plug are seen on the housing port.



Item No.	Part No.	Description	No. Req d
1	10882	Screw, Flathead	2
2	05718	Crank and Support Assembly	1
3	21607	Pin, Push	1
4	9059	Spring, Push Pin	1
5	10881	Screw, Flathead	4
6	9054	Bar, Side	2
7	9055	Plate, Attachment	1
8	17931	Gasket, Attaching Plate	1

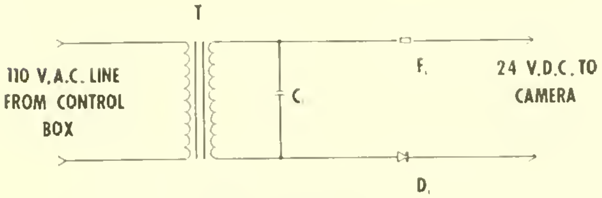
Figure 6.--Conversion schematic for adapting LB-4A film magazine to accept 400-foot external film magazine.

Figure 7.--Left side of large camera unit showing mounting plate, for power supply and take-up motor, bolted to camera top.

and to keep voltage drop to a minimum, 110-volt a.c. current is used between the vessel and the underwater cameras as a combination command signal and operating current. The camera motors require 24 volts d.c.

Conversion of the 110-volt a.c. current to 24-volt d.c. is accomplished by a compact converter package in each underwater housing (fig. 8). The converter packages are installed after being moisture-proofed by wrapping with plastic electrical tape (figs. 5 and 9).

24 V.D.C. CINE CAMERA POWER SUPPLY



T. 110-24 VOLT, 2 AMP. TRANSFORMER

C. 200 V.D.C., 2 MFD. CAPACITOR

F. .75 AMP. SLO-BLO FUSE

D. SILICON RECTIFIER, 6 AMP., 100 PIV

Figure 8.--24-volt d.c. cine camera supply schematic.

Underwater Camera Housings

The small cameras are operated in plastic housings; the large, 400-foot camera is protected by an aluminum housing.

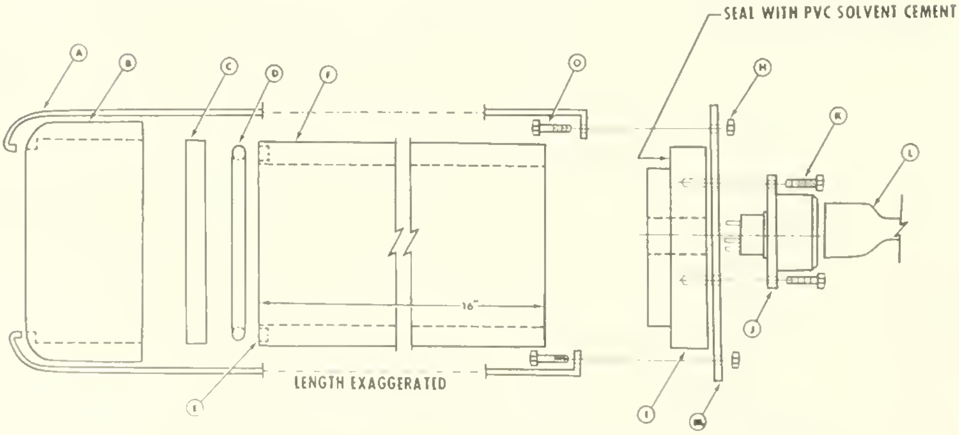
The plastic housings (figs. 10 and 11) are constructed from a 16-inch length of Schedule 120, normal impact, polyvinyl chloride (PVC) pipe, with a nominal diameter of 5 inches. The rear closure of the housing, containing a Joy receptacle, is machined from a 1-inch PVC sheet and cemented in place.

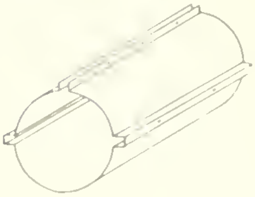
The front of the plastic housing is sealed by seating a glass port on an "0" ring. The glass port is held in place with a plastic cap and two aluminum straps (figs. 12 and 13). The camera can be quickly removed from this end for servicing. The aluminum housing for the 400-foot camera (figs. 14 and 15) is constructed from No. 6061-T6 pipe. Four wing nuts provide ample sealing. Although the housing was designed for a working depth of 300 feet, it has been successfully tested at a simulated depth of 600 feet.

Underwater Power Cable

Standard neoprene covered, 3-conductor, 12-gage electrical cable is used to transmit power to the cameras. The cable is fastened

Figure 9.--Small underwater camera housing, power supply, and camera.





PART	DESCRIPTION	NO REQ	SH NO
A	ALUMINUM CLOSURE STRAP	2	2
B	PVC END CAP	1	2
C	GLASS PORT -SEE TEXT-	1	
D	"O" RING -AUBURN NO. 11-427	1	
E	"O" RING GROOVE		
F	PVC PIPE BODY	1	
G	$\frac{3}{8} \times 1\frac{1}{4}$" STAINLESS STEEL MACH SCREW	2	
H	$\frac{3}{8}$" STAINLESS STEEL NUT	2	
I	MACHINED PVC CLOSURE	1	2
J	NO. 8118-10 JOY RECPTACLE	1	
K	STAINLESS STEEL MACH SCREW	4	
L	NO. 8118-4 JOY PLUG	1	
M	$\frac{1}{4}$ ALUMINUM SUPPORT	1	

Figure 10.--Engineering drawing of small camera housing.

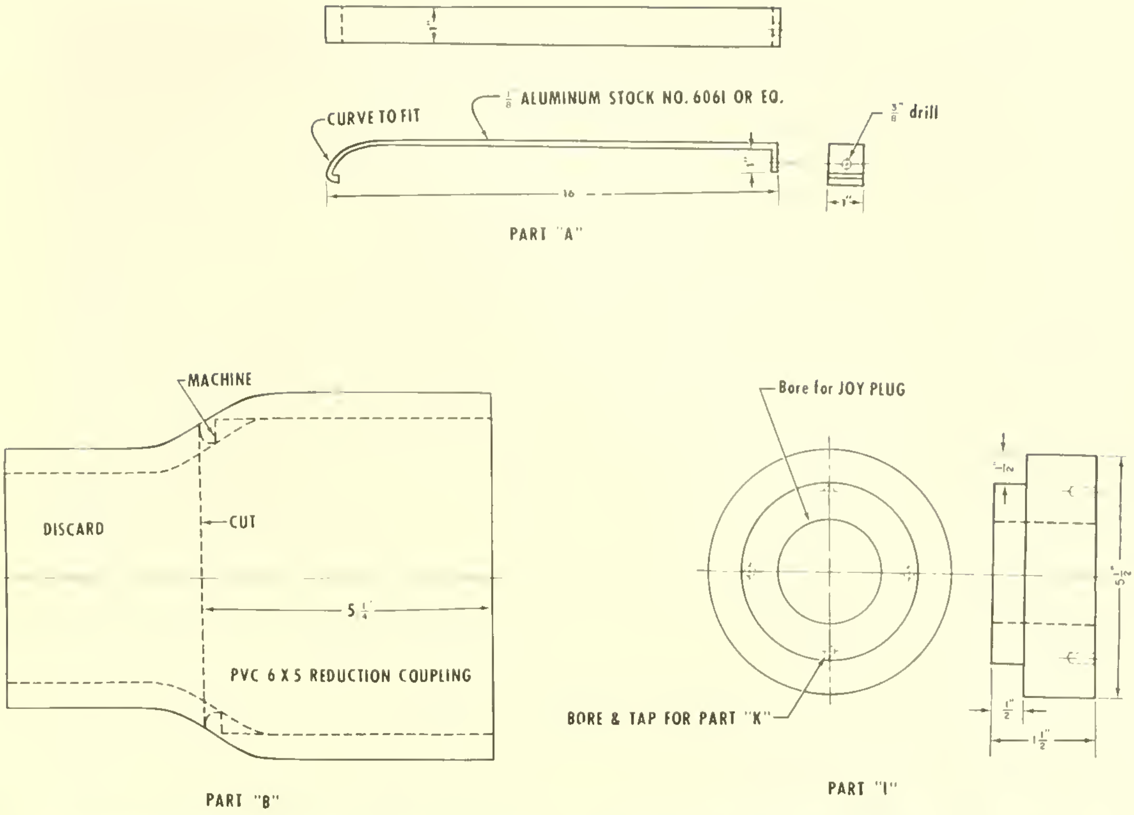


Figure 11.--Accessories for small camera housing. Mounting sleeve at lower left.

Figure 12.--Plywood-webbing camera mount showing small camera in horizontal position in adjustable aluminum stand. Front closure ring, aluminum closure straps, rear plate, and Joy plug assembly shown.

Figure 13.--Front view of plywood-webbing camera mount and small camera. Position of camera in housing is visible.

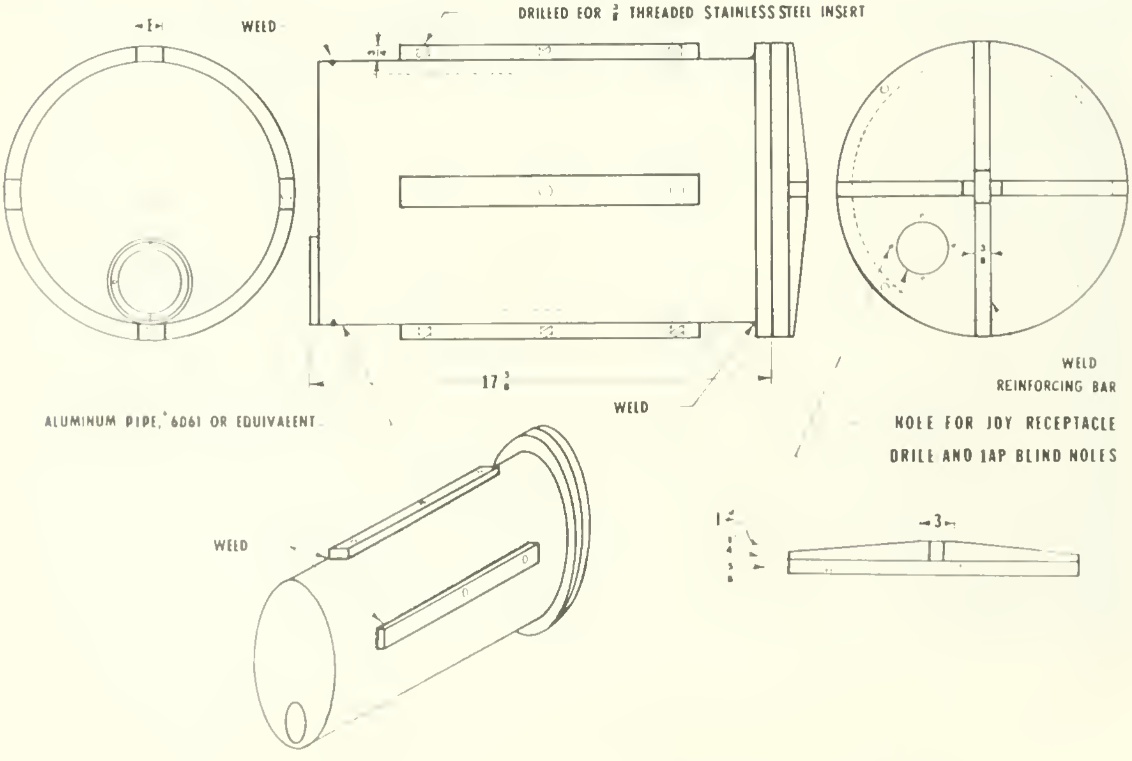


Figure 14.--Engineering drawing for large camera housing (external).

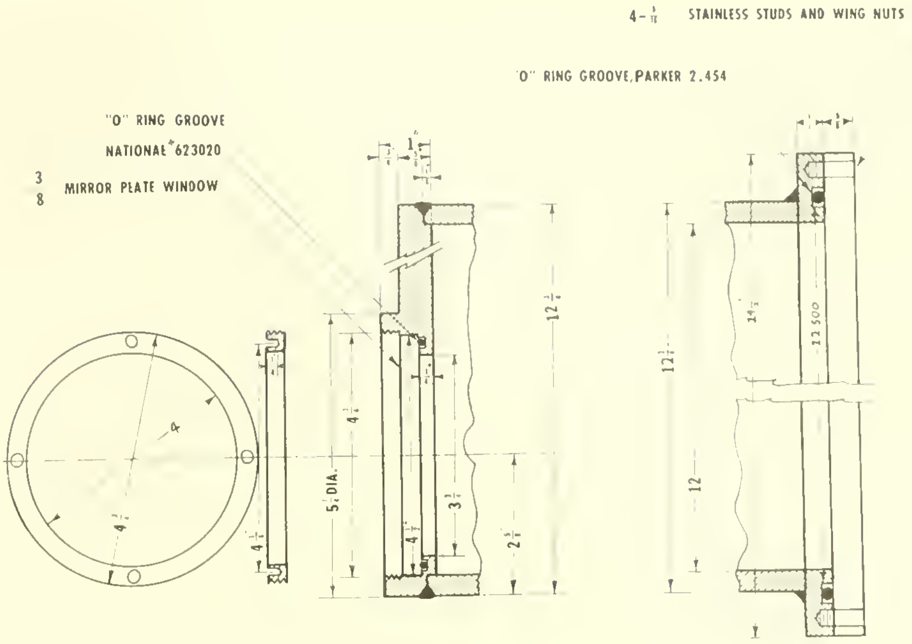


Figure 15.--Engineering drawing for large camera housing (detail).

to the trawl warp at intervals of 50 fathoms to ease the strain from water resistance. Cable to the camera housing is coupled through a male Joy receptacle (No. 8118-10), and a female Joy plug (No. 8118-4), (figs. 6 and 12). These plugs are filled with silicone grease before coupling.

Lenses

The dual lens mount of the N-9 camera permits a wide choice of lenses. Four screws release the GSAP mount and expose the "C" mounting. Wide-angle lenses of both 10- and 17-mm. focal length were used in this study

TRAWL-CAMERA MOUNTING

Methods of mounting cameras in fishing trawls vary with the needs and preferences of the individual investigator. The mounting methods used in this study can be seen in figures 2, 10, 12, 13, 14, 16, 17, 18, and 19.

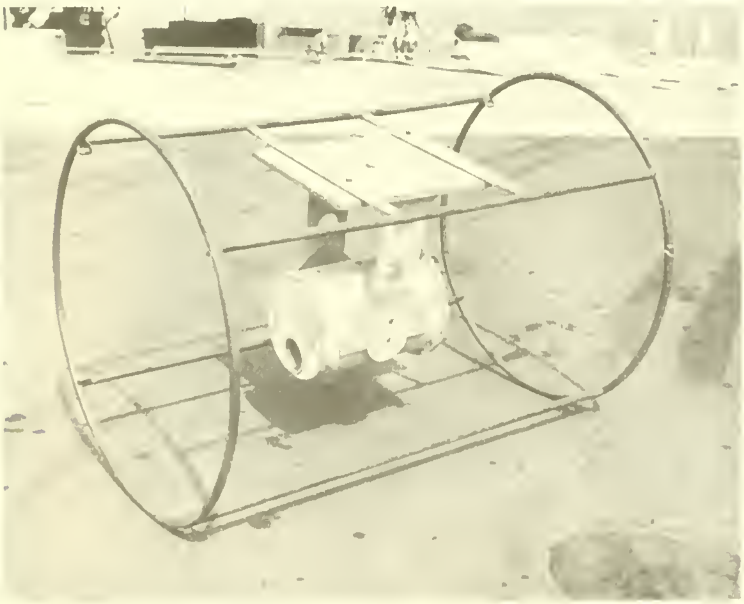


Figure 16.--Large camera housing, adjustable aluminum stand, wood mounting panel, and pipe frame for trawl throat operation. The 3-sided metal channel assembly (fig. 2) replaces the bolted mounting panel seen here.

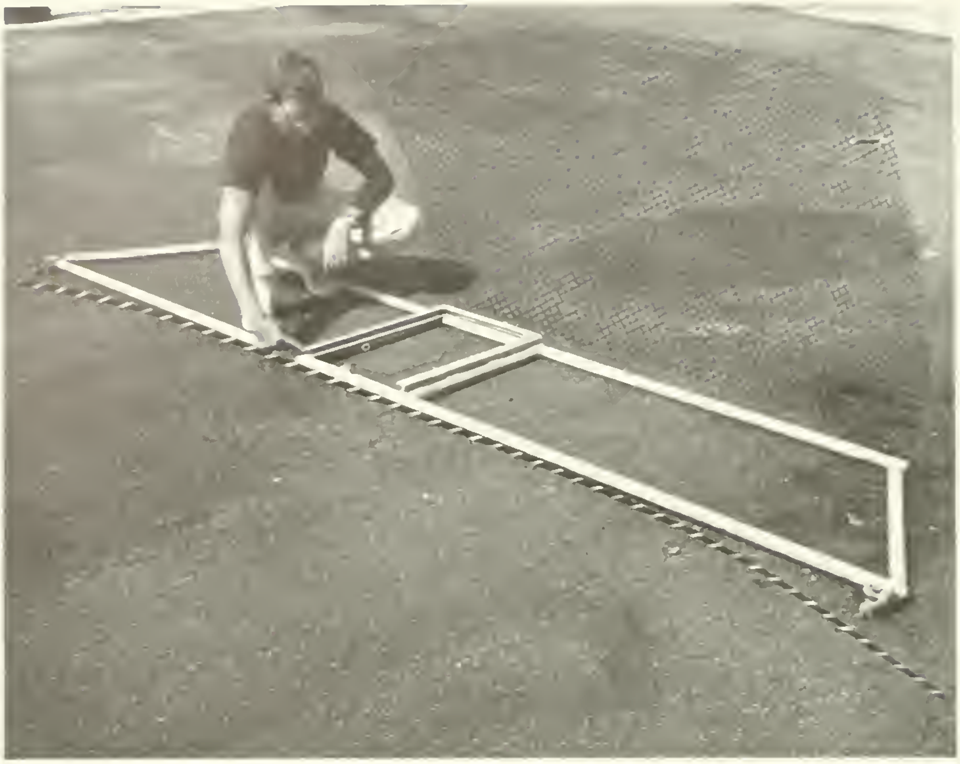


Figure 17.--Headrope-footrope camera pipe frame. Finger pointing to the 3-sided metal channel.

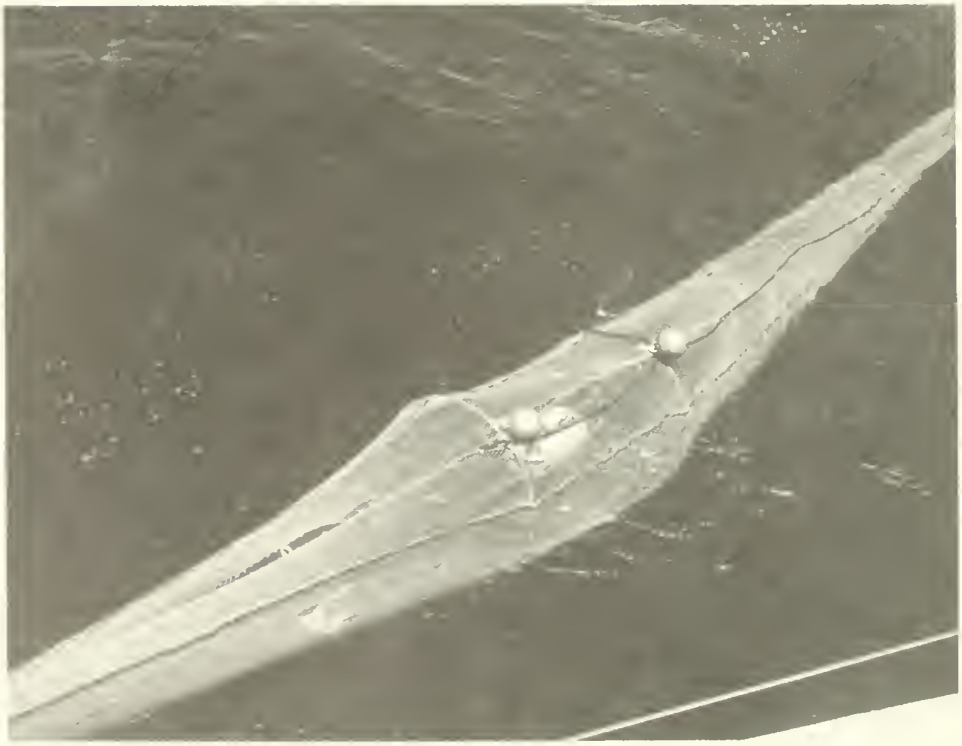


Figure 18.--Large camera mounted in midwater trawl. Metal floats prevent camera rolling.

Figure 19.--Small camera on trawl headrope. Metal frame (fig. 2) replaces plywood panel.

MASTER CAMERA SYSTEM CONTROL BOX

The portable master control box (figs. 3 and 20) permits continuous monitoring of camera operation. Elapsed running time, film run out, jamming shorts, and cable breaks are instantly detected aboard ship.

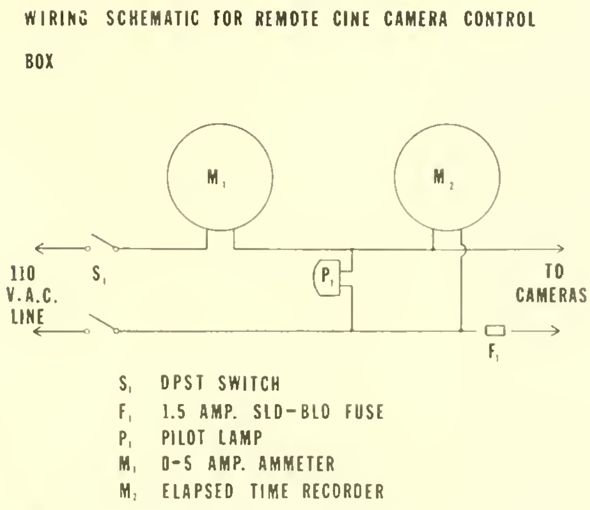


Figure 20.--Schematic wiring diagram for remote cine camera control box.

REMOTE READOUT LIGHT METER

Underwater photographic exposures cannot always be accurately predicted. A small underwater light meter that is operated from aboard ship was designed and constructed to overcome this handicap. It was not designed as a precision laboratory device, but merely as a relatively inexpensive tool for measuring subsurface light levels with sufficient accuracy for photography. Use of the meter often permits extension of photographic time, particularly in early morning and late afternoon hours.

The meter design is simple (figs. 21, 22, and 23). Basically the meter consists of a partially shielded underwater photoresistor which is focused on a neutral grey target. The light cell is connected to a small control box on the surface that houses the readout meter and batteries. The two units are connected by 300 feet of 2-conductor neoprene covered household electric cord. The light-cell end of the cable is weighted, and, in operation, is thrown overboard and permitted to sink to the required depth. The selector switch is always set on low voltage first, since operation of the light cell at values over 2 ma., will cause a breakdown.

The light meter should be calibrated while it has the same camera and film combination

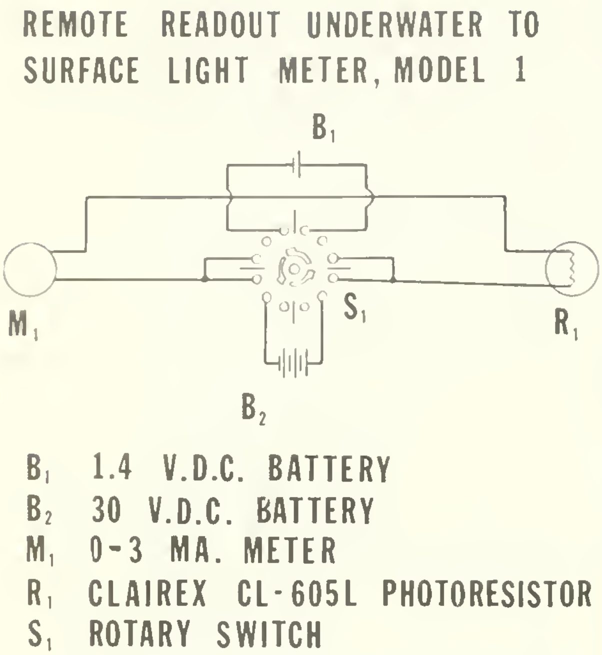


Figure 21.--Remote readout underwater to surface light meter.

Figure 22.--Underwater remote readout light meter. Underwater detector frame with grey target panel [redacted] above and light-cell housing [redacted]t. below Readout housing in center.

Figure 23.--Detector frame for underwater remote readout light meter.

TABLE 1.--Exposure table for conversion of foot-candles of available light to f-stops

ASA film rating	Foot-candles per f-stop at 1/5 of a second shutter speed								
	f1.4	f2	f2.8	f4	f5.6	f8	f11	f16	f22
16	160	320	640	1,280	2,560	5,120	10,240	20,480	---
25	100	200	400	800	1,600	3,200	6,400	12,800	---
32	80	160	320	640	1,280	2,560	5,120	10,240	20,480
40	64	128	256	512	1,024	2,048	4,096	8,192	16,384
50	50	100	200	400	800	1,600	3,200	6,400	12,800
64	40	80	160	320	640	1,280	2,560	5,120	10,240
100	25	50	100	200	400	800	1,600	3,200	6,400
125	20	40	80	160	320	640	1,280	2,560	5,120
160	16	32	64	128	256	512	1,024	2,048	4,096
200	12	24	48	96	192	384	768	1,536	3,072
250	10	20	40	80	160	320	640	1,280	2,560
320	8	16	32	64	128	256	512	1,024	2,048
400	6	12	24	48	96	192	384	768	1,536
800	3	6	12	24	48	96	192	384	768
1,000	2.5	5	10	20	40	80	160	320	640
2,000	1.3	2.5	5	10	20	40	80	160	320

that is to be used in the actual work. Calibration of the readout meter in footcandles permits rapid f-stop computations (table 1). Interpolation for various shutter speeds is accomplished by reading the requisite number of f-stop columns to the left or right in the table.

FILM

Ambient light levels below 3 footcandles dictated the use of a black and white negative film with an ASA daylight index of 500. Forced processing boosted this to effective indexes of 1,000 and 2,000.

Higher light levels will permit the use of color films, permitting greater detail to be observed. When color films are used, proper underwater color filtering is necessary.[1]

TITLING

Titling or indexing of each film roll was accomplished with the use of surplus LM-1--(1) titler (fig. 24). Alternatively, a data card can be held in front of the lens, and the camera operated while on shipboard.

RESULTS OBTAINED

Several thousand feet of usable film were obtained during midwater gear and fishing trials. The footage proved invaluable in two distinct but closely related phases of the study: (1) determining the efficiency of the gear in action and (2) studying the reaction of the fish to the trawl.

Gear Results:

The use of metric photography is a new tool in the study of trawl mechanics, and the underwater photographic system can be used to measure underwater distances accurately. The following formula permits accurate measurements to be made from the image on a film or from a TV monitor:

$$D = \frac{\left(F \times \frac{Os}{Is}\right)}{12} + 24\%$$

Where:

D = True underwater distance (corrected for underwater magnification) in feet.

F = Focal length of camera lens (inches).

Os = Object size (inches).

Is = Size of image on film (inches).

Example:

It was necessary to find the horizontal spread of a trawl mouth at a given speed. Footage taken across the trawl mouth showed an 8-inch diameter float on the far side. The float image is measured, under low magnification, and found to be 0.0333 inches in diameter. The lens has a focal length of 0.5 inches.

$$D = \frac{\left(\frac{0.5 \times 8}{0.0333}\right)}{12} + 24\%$$

D = 12.5 feet

[1] Paul J. Kruse, Jr., 1962. An underwater photographic surveillance system, paper given at the 91st meeting of the Society of Motion Picture and Television Engineers', May 1, 1962.

Figure 24.--Film titler in operation.

The formula can also be used to find the size of an object when the distance is known.

Footage of a large high-speed midwater trawl showed undulations of loose webbing. These undulations, previously undetected were the chief contributors to insignificant catches of fish. Studies showed that, although the basic design of the trawl was sound, the towing vessel was unable to reach a speed that would enable the trawl webbing to fill out.

Fish Behavior Observations:

Differences in fish behavior among species were graphically demonstrated. Schools of butterfish (Poronotus sp.) were observed vigorously swimming with the trawl. In contrast schools of anchovies passed down the trawl showing little escape reaction. Silver eels (Trichiurus lepturus) were seen drifting passively toward the codend of the trawl.

Turbid Water Difficulties:

Turbidity was an ever-present problem during the studies that led to this report. Most of the studies were carried out off the Mississippi River Delta, and several thousand feet of film were a total loss due to zero visibility. Although some areas of highly turbid water were encountered, much of the turbidity resulted from the trawl doors and footrope skimming the muddy bottom and throwing up large clouds of sediment when the trawl was operated too close to the bottom.

TV MONITORING

The original system called for a closed-circuit TV chain, coupled to an underwater motion picture camera. A desired sequence, on the TV monitor, would be permanently recorded by the motion picture camera. This would have permitted higher quality motion pictures (black and white, or color) than could be photographed from a TV monitor. Problems such as turbidity, camera alignment, fish reaction, and changes in the trawl could have been observed and changed at sea.

A TV chain, previously purchased by the Base for another project, was adapted for underwater operation by the design and construction of a lightweight underwater housing, which is highly satisfactory and relatively inexpensive (figure 25). Waterproof electrical connectors for underwater TV application are available.

The TV system was not used in the midwater trawl camera studies because of mechanical difficulties concerned with handling the 18-conductor cable required for that par-

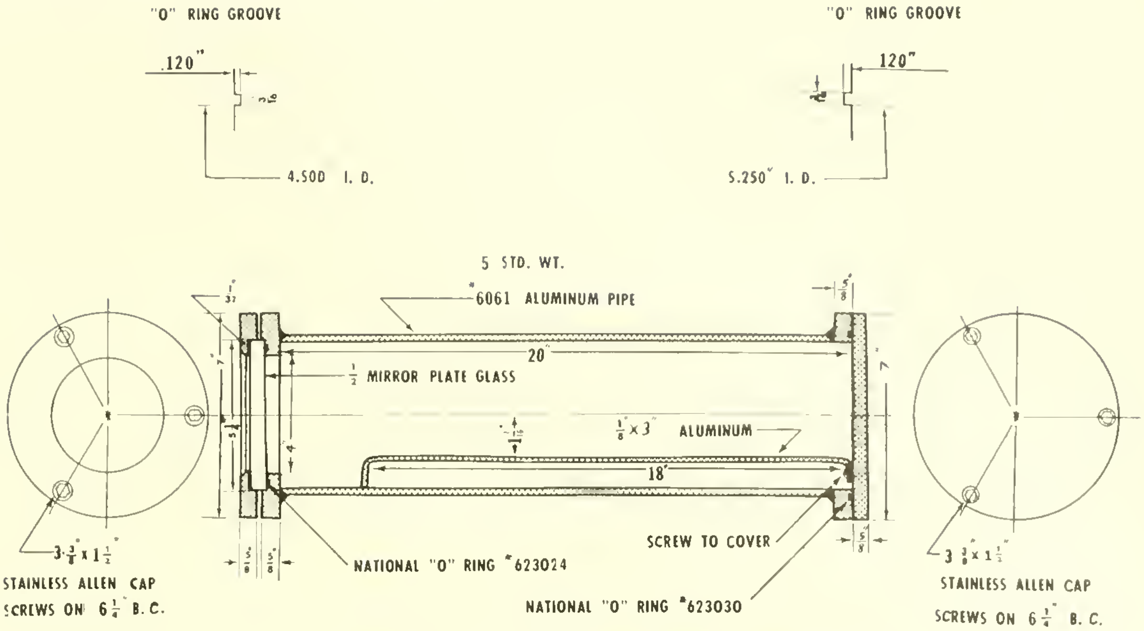


Figure 25.--Engineering drawing for underwater TV camera housing.

ticular TV camera. Such a cable is difficult to handle, not only because of its bulk and unwieldiness, but also because each of the conductors represents a separate potential source of mechanical and electrical failure. Newer closed-circuit TV systems are available which require only three conductors.

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1959. Exploratory fishing for sardine-like fishes in the Gulf of Mexico. Proceedings of the Gulf and Caribbean Fisheries Institute, Eleventh Annual Session, November 1958, p. 38-40.

MS # 1341

TABLE 2.--Sample data sheet used in camera study

Station No. ____________
Date ____________
Time ____________
Surface ft./c ____________
Film ____________
ASA No. used ____________

Camera body ____________
Camera mag. ____________
Film mag. ____________
Roll No. ____________
Housing No. ____________

Time	Seq. No.	Start	Stop	Film	Cum. film	Frames	Cum. frames	Shutter speed	Film speed	Stop	Depth	Focus	Above bottom	
		Seconds	Seconds	Feet	Feet	Number			F.P.S.		Fathom	Feet	Fathom	

GPO 878-188

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